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Agricultural Production Systems and Environmental Health

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By the turn of the century, American farmers and ranchers will be producing food and fiber through the application of highly sophisticated systems that involve a broad spectrum of relevant factors—from soil type, to options for fertilizer and pesticide use, to markets and other economic information. These systems will help farmers and ranchers better match land use to land capability, apply needed conservation practices, make environmentally sound production choices, and lower production costs. Most importantly, they will aid in selecting the best combinations of chemical and the biological means for producing and protecting plants and animals. The systems will also help complement currently available and new classes of chemicals with biological control mechanisms such as natural predators and naturally occurring protective phenomena such as allelopathy and other forms of resistance to insects, weeds, and disease. Additionally, they will incorporate the use of biodegradable, slow-release, or timed-release natural and synthetic pest control materials. Also, scientists will increasingly emphasize nutrition and food safety in the development of plant and animal germplasm and production and processing methods.

In the twenty-first century, American farmers and ranchers will be called on to produce safe, high-quality food in sufficient quantity to meet both domestic and foreign demand, without compromising the environment. These are not incompatible goals.

In fact, American agriculture is already doing a good job in this regard. The food produced on the nation's farms and ranches is safe and nutritious—Americans have never lived so long or been so healthy. Certainly, we are producing more than enough food to meet demand—the farm surpluses are testimony to that. If there is an area in which we fall short, it is environmental protection.

Achieving environmental protection has not failed for lack of trying, and it is not the result of a callous attitude toward the environment. Farmers and ranchers, government, and agricultural industry share the concern of environmental groups for a cleaner environment and want to improve it. The Agricultural Research Service (ARS) has worked closely with agricultural industries for years, and personal experience confirms that industry generally has conservation of natural resources as a fundamental objective.

Most people recognize that agricultural production contributes in some degree to environmental degradation. Although agriculture sometimes gets a disproportionate share of the blame, some problems clearly can be laid at agriculture's door. These include: soil erosion on farmland and resultant sedimentation of streams and lakes; occasional pollution of ground and surface waters by agricultural chemicals; and depletion of groundwater and salinization caused by excessive irrigation in arid and semiarid areas.

One challenge for the twenty-first century will be to ameliorate these problems without reducing our production capability. Improving environmental quality is already among our highest research priorities. More specifically: twenty-first century American farmers will rely on increased use of biological pest controls to complement their use of man-made agricultural chemicals; they will find new ways to control insects with smaller amounts of chemical pesticides more carefully applied; they will use products of the new tools of biotechnology; and they will use highly sophisticated systems that synthesize the broad spectrum of factors relevant to production—from soil type, to options for fertilizer and pesticide use, to markets and other information.

In the years to come, we shall see a continued blending of the so-called low-input, or organic, with conventional farming methods. Most conventional farmers already use low-input practices, such as crop rotations or mechanical weed controls and minimal use of pesticides.

The high-tech agriculture of the future will require better chemicals for specific uses. These chemicals will be more selective, better targeted, and safer. And they will be complemented by such biological pest controls as natural predators and naturally occurring protective

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phenomena such as allelopathy and other forms of resistance to insects, weeds, and diseases.

The nation's future farm production policies will need to remain flexible. There will probably be times, such as now, when depressed global demand will mean surplus production. There will be other times, such as in the 1970s, when high global demand will spur production on American farms and ranches. Many experts think that a period of expanding worldwide demand for agricultural commodities is coming soon—within even the next 2 or 3 years. Increasingly, the industrial use of agricultural commodities will help buffer these fluctuations in demand. Cornstarch, for example, is already used to make a variety of products, from filters to plastic film.

Research is already moving in these new directions. Regarding biological pest controls, the ARS has defined such controls in the broadest possible way. Biocontrol means more than the traditional releasing of natural enemies of pests, from tiny predatory wasps to *Bacillus thuringiensis*. It also means breeding pest resistance into crops, as ARS scientists recently did when they transferred resistance to the Colorado potato beetle from a wild to a domestic potato. It means using insect pheromones as an aid to control the pests. It means synthesizing and applying natural chemicals that inhibit growth or otherwise neutralize pests. We can call these approaches biorational in that they do not upset the natural biology.

Several years ago, an ARS scientist detected the fungus Pythium on the roots of no-tilled wheat in the Pacific Northwest and determined that Pythium was the culprit behind reduced yields. ARS researchers then isolated a bacterium that can shield roots against Pythium.

Biological controls also are often used in concert with chemical controls—the concept of integrated pest management (IPM). A good example of IPM is occurring in North Carolina in the eradication of the boll weevil. The term "eradication" is used advisedly, because if we drop our guard, the weevil will surely come back. At any rate, the program is as follows:

- First, weevil traps containing sex attractants called pheromones are placed in cotton fields in late summer. The number of weevils trapped tells scientists how heavily infested the fields are.
- Then, the insecticide malathion is sprayed in September, before the weevils can store up enough fat to survive the winter. The farmers plow under the cotton stubble after harvest to destroy the weevils' breeding ground.
- Follow-up trapping and spraying the following year catches any weevils that survive the first round of spraying.
- A few traps are left in the fields to detect surviving strays. If reinfestations become economically significant, farmers can respray.

The boll weevil eradication program in the Carolinas began in 1978 and has proven so effective that it is now being extended to Georgia and Alabama. It shows that a judicious combination of biological and chemical controls can control a serious pest without excessive spraying.

Controlling the boll weevil has allowed North Carolina cotton farmers to reduce annual pesticide costs by nearly $30 an acre, and to increase profits by almost $70 an acre.

Even when chemicals appear to be the best answer, we are refining application methods so that only minute quantities of chemicals provide adequate pest control. These methods provide an economic incentive to the farmer, and they leave little residue behind in the environment.

Another significant factor in future farm production will be biotechnology. The influences of biotechnology will increasingly be felt in all phases of agricultural production and processing, including better disease protection and growth characteristics in plants and animals, better stress resistance, better ways of processing harvested crops, better ways to protect the environment, and others.

Specific biotechnology projects include the following: Scientists in an ARS laboratory have cloned bacteria genes to produce more of a particular enzyme that breaks pesticides down quickly into harmless components. These genetically engineered bacteria have been proven effective in degrading large amounts of pesticides, for example, in animal dips or leftover pesticides in field tanks.

Scientists at the ARS Plant Gene Expression Center in Albany, CA, have isolated the gene sequence that regulates production of ethylene in fruits and vegetables. Ethylene is a trigger that controls the ripening process. This exciting development could lead to a greatly extended shelf life for fresh fruits and vegetables. Perhaps now we will be able to develop and use inhibitors to delay ethylene production, and therefore delay ripening. Ethylene could then be added later when we want those products to ripen.

The amount of new knowledge that we will possess in the twenty-first century will be staggering. How will our farmers keep from becoming awash in a sea of information? They will use sophisticated, computer-based production systems that consider all aspects of farming in a holistic way.

These systems will consider the entire process of agricultural production as a continuum, from natural resource management to economics to food safety to environmental quality. They will help farmers bring diverse fields of knowledge together to match land use to land capability, apply needed conservation practices, make environmentally sound production choices, and lower production costs. They will help farmers select the best combination of chemical and biological means for producing and protecting plants and animals.

One such system is already helping cotton farmers increase their profits by $60 an acre. This system is called Comax, which stands for Cotton Management Expert. It is a plant physiology model that mimics the thinking of human experts in cotton culture. Comax not only churns out data, it interprets it. At first, Comax

helped farmers decide when and how much nitrogen fertilizer to apply and when to harvest the crop. Now, it is being expanded to include models for control of insects, weeds, and diseases. Eventually, it will include environmental choices as well.

Comax is one of several ARS-developed expert systems that farmers can run on their personal computers at home. Another is a conservation-production model for use in the Corn Belt that merges conservation and production needs for corn growers. These are not pie-in-the-sky schemes. It is getting harder and harder to find a farm office without a computer. With continued development of these systems, computers will become even more valuable.

These systems, as I see them, are the key to future food production in the United States. They will help farmers see the big picture as they make their production decisions, and they will help achieve the goals of ample production of safe food in an environmentally safe way.